On the development of the bulb of the adder's-tongue.

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WITH PLATES VII AND VIII.

Hundreds of small plants of the adder's-tongue, or spring lily (*Erythronium Americanum* Ker.) are found in the spring with the bulbs less than five inches below the surface of the soil, each bearing a single leaf and no flowers, while comparatively few plants bearing two leaves and a flower each are found, and bulbs of these are at depths varying from five to nine inches.

The question has been raised as to the method by which the mature bulbs reach their great depth.

Early in March, 1893, I helped to fill a window box with surface mold taken from the woods, containing small bulbs of the *Erythronium*, apparently seedlings. These bulbs, which were found less than three inches from the surface of the ground, developed each its single leaf (fig. 1), which died down in a month or so. When the earth was removed from the box to make room for other plants, the bulbs were found to have developed runners with bulb-like thickenings at the ends (fig. 7). Having thus gained a clue as to the way in which the bulb of a flower-producing plant is formed at the depth at which it is found, many other plants were examined in various stages of development. The bulbs of the plants which produced flowers this year are called flowering bulbs in these notes, in distinction from those of the younger plants which are termed seedlings or secondary bulbs according to size and age.

The runners start from the bottom of the bulb, but vary both in length and direction of growth, being from two to nine inches long, and ranging from perpendicular to nearly or quite horizontal (figs. 2–5). As the supply of nourishment in the parent bulb is exhausted, the tip of the runner thickens into a secondary bulb, which sends out rootlets from the upper part (fig. 11), and then the runner is absorbed, leaving, in the cases examined, nothing but a dry and empty husk of the parent bulb and runner. These secondary bulbs later in the season lose their fleshy rootlets from the upper part of the bulb and send out the fibrous roots from the base.

The number of runners varies from one to three in the plants examined, and they grow in different directions. These runners are from two to nine inches long, so that if they grew vertically the bulb might be formed at the depth of the flowering bulbs, but they run obliquely more frequently than vertically thus leaving the secondary bulbs nearer the surface than the mature ones. The secondary bulb, after reaching the depth of the flowering bulb, does not always blossom the next spring, for bulbs with six inches of soil above them have been found with one leaf each (fig. 8).

On May 30th the leaves had in most cases disappeared so that it was with difficulty that a few plants with fruit and decayed leaves were secured, while the soil was filled with the fleshy runners and newly formed secondary bulbs. These runners were often found on the surface of the soil, protected by the mulching of leaves. In such cases the new bulb is but very little, if at all, deeper in the soil than the parent.

The flesh of the mature bulb is firm and white, and leaves a white coating of starch on a knife with which it has been cut. When crushed between the fingers, it becomes sticky as it dries. The starch grains are about half the size of those of the potato, measuring from .010^{mm} to .042^{mm} in length and from .007^{mm} to .035^{mm} in breadth. The mature bulbs do not produce runners.

Plants frequently grow so close together that they indent each other, and adhere strongly one to the other, but no break in the skin at the point of contact was seen although looked for carefully. These clusters of bulbs are formed by buds which the mature bulb sends off from its base as was seen on November 4th, and in a very large one on November 30th. There was no runner present, but in other respects the bud corresponds to a secondary bulb, and comes to maturity in close contact with the parent. This budding is carried on for an indefinite period, two buds of different sizes sometimes being formed on the same bulb.

Plants examined in July, on September 18th, and on October 30th, showed no new developments except that the runners and the parent bulb had both disappeared save traces of the epidermis.

On November 1st, I examined, without a lens, a number of small bulbs which had been taken a couple of days before from just below the surface of the soil, in the same place in

which the runners were so plentiful on May 30th, and where blossoms had been abundant earlier. These small bulbs were not more than a quarter of an inch long, and, mistaking them for seeds, they were cut open in search of the embryo. They proved to be bulbs, for within each there was a sprout formed of the single leaf, extending the length of the bulb, and root fibers were clustered at the base.

These small seedlings had a loose husk or epidermis similar to that of the older ones, but not quite so dark in color. The mature bulbs had not softened since their time of blossoming early in spring. They were as firm on November 1st as on April 8th.

On November 4th a microscopical examination of sections cut from bulbs of various ages was made. A vertical section of a mature bulb showed a sprout of a yellow color, made up of several layers running up through the flesh near one side (figs. 21, 22). The outer of these layers was formed by the two foliage leaves enclosing the bud of next spring's flower. This flower bud was more than half as long as the whole bulb and its parts were well advanced. The perianth was nearly colorless, but the leaves were quite yellow. The stamens were nearly three-eighths of an inch in length, of which the anther was more than half. The anthers were filled with pollen, the grains of which were four times the size of the starch grains. The pistil was five-sixteenths of an inch in length, the ovary being one-eighth of an inch long. The projections on the placentæ from which the ovules are developed were seen and showed a dark center.

After removing the husk, the tip of a fresh specimen was seen to be made up of two modified leaves, or leaf scales, one completely surrounding the other except at the tip where the sprout and inner scale push through. The pressure on the edges of this opening compresses the flesh on the one side of the tip but makes it spongy on the other. These two tips, one within the other, gave the impression that the root is a true bulb, being formed of modified leaves, which was afterwards confirmed by studying the sections, and by comparison of the definitions of corm and bulb, and the examination of examples of each.

A section cut from the bulb a quarter of an inch below the tip showed the sprout to be composed of concentric layers which are the foliage leaves enclosing the perianth and other

parts of the bud. The epidermal cells were distinguishable at the middle of the outer leaf, which completely surrounds the inner one and overlaps, but the inner one does not meet around the enclosed flower-bud, as is shown in fig. 23. This is the character of the bulb scales, the outer one overlapping at the edges, which in its altered growth have united so that there is formed a continuous layer of very starchy flesh, which varies in thickness from one-sixteenth to three-sixteenths of an inch. The inner leaf and the inner scale agree in only partially surrounding the parts within it, and each is thinner than its outer fellow (fig. 18).

A second section showed each of the anthers to be composed of four pollen chambers, united by a delicate structure. The partition between the two in each of the lateral pairs of anther cells was thinner than that which separated these lateral pairs (fig. 24). In the later growth of the flower the thinner of these sets of partitions is broken through and thus each lateral pair becomes a single cavity forming "two-celled anthers" described in the manuals. In the center the three lobed style is seen in section. It shows the tube in each lobe through which the pollen is enabled to reach the ovules (fig. 23). These tubes of the style begin to expand, in a third section, into the cells of the ovary. The lateral pairs of anther cells have drawn away from each other and the partition separating the cells of each pair is thinner than in the previous section.

The edges of each sepal were turned inward at almost a right angle and indented the petals deeply, forming a groove on either side of the midrib of each petal. The petals in turn bent their edges inward, forcing them between the lateral pairs of anther cells on the alternate stamen (fig. 23). In the fourth section there is a more marked yellow tint to the perianth than before noticed.

The ninth section shows the line which marks the surfaces of the leaves which through modification form the pistil. On the involute margins of these leaves, forming the placentæ, the ovule masses appear, which are seen to be outgrowths from the edge of the leaf itself (fig. 25).

In the tenth section the union between the filaments and the midvein of the petals was clearly seen. The anthers do not adhere to the filament for their whole length as one of the filaments dropped away from the anther cells in this section.

An external bud, at the base of the bulb, contained a single leaf in a state of development corresponding to that of a bulb

a quarter of an inch long. The upper surface of the leaf was marked by a line extending partly across the sprout.

On examining the bulbs a quarter of an inch long, from the seeds of last spring's flowers, the leaf was merely a round yellowish body having a line extending nearly across it, showing where the upper surface of the leaf was to be. In a bulb half an inch long, the leaf is convolute and its surfaces are free from each other. In an intermediate bulb, the leaf was convolute above and conduplicate near the base.

On November 29th a large bulb was found which had a bud almost entirely separated from the parent bulb, and there was also a bud forming at one side which had the sprout well developed but the line of separation was indicated only by a notch on one side. A similar bulb examined December 6th is shown in figs. 17 and 18.

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Explanation of Plates VII and VIII.

The figures of Plate VII are taken from blue prints which were made from pressed specimens. They are reduced a little more than one-half.

Fig. 1. Seedling plant in leaf.—Fig. 2. Seedling with growing runner.—Fig. 3. Seedling with runners started in opposite directions.—Figs. 4, 5. Runners in active state. Fig. 4 is 9 inches from base to tip, in a straight line; fig. 5 is 8 inches from base of longer runner to its tip, omitting bends.—Fig. 6, 7. Runners developing secondary bulbs.—Fig. 8. Plant with six inches of soil above the bulb, bearing one leaf and no flower.—Figs. 9, 10. Secondary bulbs formed at the ends of runners. The longest runner of fig. 9 is 7.25 inches long; the longest in fig. 10 is 7.75 inches long.—Fig. 11. Runner having rootlets from upper part of the secondary bulb. This runner grew at nearly the same angle as the one in fig. 4.—Fig. 12. Mature plant bearing two leaves and a flower.

The figures of Plate VIII were drawn directly from the specimens. The sprouts had developed so rapidly that some of the points seen on Nov. 4th had disappeared to a considerable degree, having grown from ¼ to ¾ of an inch in the month. The figures were made during the week ending Dec. 9th, from bulbs dug Nov. 29th.

Fig. 13. A seedling bulb.—Fig. 14. Secondary bulb showing sprout protruding.—Fig. 15. Mature bulb showing sprout, a small bud, *a*, and a larger bud, *b*, under the epidermis or husk.—Fig. 16. Mature bulb with one bud nearly separated, *b*, and another less advanced, *a*.—Fig. 17. Mature bulb with bud nearly independent of parent at *b*, and a second less mature one at *a*.—Fig. 18. Cross section of fig. 17; *l*, the bases of the leaves sheathing the stem, *sm*; *l'*, the single convolute leaf of bud *b*. The heavy black lines in this and the following figures are empty spaces between the flesh of the bulb and the sprout.—Figs. 19, 20, 21. Vertical sections of 13, 14, 15, respectively.—Fig. 22. Vertical section of mature bulb showing the flower; *p*, perianth, the tips of its lobes enclose the stamens, *st*, the style and stigma, *s*; *o*, ovary; *sm*, stem; *l*, bases of foliage leaves.—Fig. 23. Cross section of sprout showing the four celled anthers, the style, perianth and leaves. The anthers are distorted by pressure in the bud. ×3.—Fig. 24. Cross sections of single anther. ×32.—Fig. 25. Section of ovary showing the lines which indicate the surfaces of the leaves from which it is developed, and the formation of ovules on the margins of these modified leaves. ×35.—Fig. 26. Section of older ovary. ×20.